# Teacher Guide
## Nutrients in an Estuary

Featured NERRS Estuary:
Guana Tolomato Matanzas National Estuarine Research Reserve, Florida
https://coast.noaa.gov/nerrs/reserves/gtm.html

## Activity Summary

In this activity, students model estuaries, artificially enriching freshwater and saltwater samples with different amounts of nutrients and observing the growth of algae over several weeks. Students relate their results to the phenomenon of algae blooms in estuaries. They then analyze data for different sites at the Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR) in Florida to discover the relationships between nitrogen, chlorophyll, and dissolved oxygen. Finally, they study how nutrients cycle through an estuary and suggest recommendations for reducing nutrient inputs to estuary waters.

## Learning Objectives

Students will be able to:

1. Understand how water quality and nutrient parameters in an estuary can indicate disruptions to ecological processes in estuaries.
2. Interpret data from an experiment to explain the effects of over-enrichment on water quality and living things; and relate this lab experience to the phenomenon of algae blooms and eutrophication in an estuary.
3. Explain the phenomena of algae blooms and eutrophication in terms of total nitrogen, chlorophyll-a, and dissolved oxygen.
4. Describe the effects of eutrophication on the nitrogen cycle.
5. Explain how nutrients cycle in an estuary and how natural processes and human impacts affect this cycle.
6. Identify sources of nitrogen inputs to estuaries and identify some ways to limit them.

## Grade Levels

9-12

## Teaching Time

- 1 (55 minute) class session, plus periodic observations every 2-3 days over three weeks (Part 1)
- 3 (55 minute) class sessions (Parts 2 and 3)

## Organization of the Activity

This activity consists of 3 parts which help deepen understanding of estuarine systems:

Nutrients in an Estuary

Using Data to Study Eutrophication and Conditions in an Estuary

Eutrophication and the Nitrogen Cycle

## Background

### Eutrophication and Algal Blooms

An overload of nutrients, called eutrophication (Greek for "good-nutrition"), can be harmful to estuaries. This phenomenon is also referred to as "over-enrichment," or "nutrient pollution." The consumption and recycling of nutrients tend to keep nitrogen levels balanced because bacteria release nitrogen back to the atmosphere at a greater rate than the natural flow of nitrogen into the estuary and the rate of nitrogen fixation.

Over-enrichment often causes "algal blooms" (or sometimes HAB "harmful algal blooms" in cases where the **phytoplankton** are toxic to marine organisms or humans) in estuaries. The influx of high nutrient levels causes excessive growth of algae. Too much phytoplankton in the water column can cause the water to become cloudy, reducing the amount of sunlight available for underwater plants to photosynthesize. Large algal mats floating on the surface can block the light that underwater plants such as seagrasses need. Disturbances to seagrass communities can be harmful to other organism like fish and crabs that depend on the grasses for food, shelter, and nursery areas. On sunny days, the algae's photosynthesis pumps abnormally high levels of oxygen into the water. When algae die, it sinks to the bottom where it is decomposed by bacteria. This process removes oxygen from the water. As bacteria decompose algae, more oxygen is consumed. If too much oxygen is removed from deep waters, the small organisms feeding fish and crabs will die off. Fish and other predators may die themselves or move to other areas in search of more oxygen.

Algae blooms can disrupt food webs, damage estuarine habitats, and deplete oxygen to the extent that organisms die or move out. The conditions created by these blooms may encourage only species that can tolerate eutrophic conditions (e.g., blue-green algae). In addition, the appearance of the cloudy water and decaying algae mats, unpleasant odors, and loss of estuarine species can diminish the recreational value of estuaries.

Algal blooms may result from natural conditions, but they are often linked to excess nutrients coming from human activities. Excess nutrients may come from septic tanks, wastewater treatment plants, point source discharges from sewage and industry, exhaust from cars, emissions from industry, fertilizers from lawns, golf courses, farms, and animal waste (especially from livestock). Sources of nitrogen that do not enter estuaries directly from point sources are transported to estuaries by stream flows, rain, leaching, groundwater, storm water, and as emissions carried through the air.

Algae blooms usually occur seasonally. In the northern hemisphere, they typically occur between May and October. Heavy use of fertilizers in the spring combined with spring rains can introduce excess nutrients to an estuary. Other conditions that favor algal blooms come into play in the months from summer to fall: bright sunlight, still water, and sharp temperature gradients that keep warmer surface water and colder bottom water from mixing.

Algal and phytoplankton blooms can be tracked by measurements of chlorophyll-a. Chlorophyll-a is a pigment found in phytoplankton that is involved in photosynthesis. Concentrations of chlorophyll-a are used as an indirect measurement to determine phytoplankton abundance. Concentrations are measured in units of µg/L (micrograms per liter).

### Algal Blooms and Nutrient Residence Time

The chance that particular sites within estuaries will experience algal blooms depends on a number of conditions. These include:

- The amount of nutrient input.

- Water quality parameters such as temperature and salinity.
- Weather and seasonal conditions.
- The residence time of nutrients in the estuary. This is determined by factors such as stream flow, tidal flushing, winds, water depth, and water stratification. These determine whether nutrients will stay in the estuary long enough to alter the nitrogen cycle enough to instigate an algal bloom.

From May 2002 to August 2003, researchers at the Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR) in Florida studied how water chemistry and the hydrodynamic factors that govern residence time affect plankton abundance in the lagoons of East Florida. Over a sixteen-month period, they measured nutrient levels and plankton abundance (chlorophyll-a concentrations) at eight sites in the reserve. (A Comparison of Water Quality and Hydrodynamic Characteristics of the Guana Tolomato Matanzas National Estuarine Research Reserve and the Indian River Lagoon in Florida, Phlips, et al., 2004 in Journal of Coastal Research, Special Issue No. 45, 2004.)

Researchers considered all the factors determining nutrient loading (including nitrogen and phosphorous inputs from all sources) and developed an index (Nutrient Load Index, or NLI), from 1-4, that describes how heavily the site is usually loaded with nutrients (1 represents a low load, 4 represents a high load). They also developed an index categorizing the sites according to estimated water residence times (RTI) on a scale of 1-4. This was done by summarizing the factors that determine tidal flushing, including tidal excursion, freshwater inflows, wind, water stratification, and depth. The index describes the extent to which nutrients generally remain in the estuary, or are flushed out (1 represents a short residence time, 4 represents a long residence time).

Their findings indicate that regions with short water residence times have lower peak phytoplankton abundance than regions with longer residence times (at least under normal to high rainfall conditions, not accounting for drought). In fact, this held true despite differences in nutrient load index. Sites that had a high residence time index (index of 3 or 4) did not have the highest peak or average chlorophyll-a concentrations even if they had high nutrient load indexes.

## National Science Education Standards

### Content Standard A: Science as Inquiry

A3. Use technology and mathematics to improve investigations and communications.

A4. Formulate and revise scientific explanations using logic and evidence.

A6. Communicate and defend a scientific argument.

### Content Standard B: Physical Science

B6. Interactions of energy and matter

### Content Standard C: Life Science

C4. The interdependence of organisms

C5. Matter, energy, and organization in living systems

### Content Standard F: Science in Personal and Social Perspectives

F3. Natural Resources

F4. Environmental quality

F5. Natural and human-induced hazards

F6. Science and technology in local, national, and global challenges

Four of the sampling sites were on Florida's northern east coast within the GTM NERR, which is defined by barrier islands. These sites were all relatively close to ocean inlets and as a consequence, all had relatively low residence times (RTI of 1 or 2). The four other sites were sub-basins of the Indian River Lagoon located on the central east coast. The lagoon has a several ecologically distinct basins that differ significantly in their hydrodynamics, water chemistry, and biological features. Their residence times varied, but two of the sites had RTI of 3 and 4.

All eight sites represented different combinations of nutrient load index and residence time index. Graphs illustrating the combined influence of these two factors on phytoplankton abundance are shown below.

The study also analyzed total nitrogen (TN) and dissolved inorganic nitrogen (DIN) concentrations and chlorophyll-a concentrations at all eight sites. The authors of the study acknowledge: "The absence of well-defined relationships between nutrient concentration and phytoplankton biomass (i.e. chlorophyll-a) is not unusual for estuarine ecosystems, even those subject to substantial eutrophication (Borum, 1996; Cloern, 2001)." p. 15, Journal of Coastal Research, Special Issue No. 45, 2004.

However, it is still worthwhile for students to analyze this data and see if they can observe patterns. In fact, the authors found significant correlations between chlorophyll-a and TN at all four Indian River lagoon sites. They found no significant correlations between chlorophyll-*a* and TN within the GTM NERR sites.

## Preparation

- You may want to begin Part 1 of this activity two to three weeks before you begin Parts 2 and 3.
- Assemble materials (See material list).
- Contact the landowner and ask for permission before collecting the water samples needed for this exercise. Collect pond and/or estuary water samples that include algae. The amount of water needed will depend on how many samples students your will treat or control. If estuary water is not available, use pond, stream, puddle, or tap water samples.
- Determine where in your classroom student groups will place their experiment so that all the beakers will get the same amount of sunlight or ambient light. (Note: If you decide to have students design their own experiments, you can allow them to determine if light is a variable to alter.)
- Optional: Set up different sets of beakers yourself and label them prominently. (Note: Ideally students prepare the beakers themselves.)

## Materials

### Students

- ❑ Need to work in a computer lab or with a computer and projector
- ❑ Copy of Student Reading—Introduction to GTM NERR
- ❑ Copy of Student Reading—Nutrients in an Estuary
- ❑ Copy of Student Worksheet—Nutrients in an Estuary
- ❑ Copy of Student Data Sheet—GTM 2002-3 Nutrient Data

### Teachers

- ❑ Water source (preferably from an estuary) with algae
- ❑ Liquid plant fertilizer
- ❑ Sea salt
- ❑ Measuring teaspoons
- ❑ 600 ml beakers
- ❑ Safety eyewear
- ❑ Digital camera

Equipment:
- ❑ Computer lab or
- ❑ Computer and Projector

## Preparation

- If you are unable to download software to your computers then we recommend using Google Maps (https://www.google.com/maps). The following link provides an excellent tutorial for you and your students on creating and sharing google maps (https://support.google.com/mymaps/answer/3024454?hl=en).
- Bookmark the eutrophication animation below to use during Part 3 of the activity. http://coseenow.net/blog/2008/11/eutrophication-animation/.
- Make copies of the *Student Reading—Introduction to GTM*, *Student Reading—Nutrients in an Estuary*, *Student Worksheet—Nutrients in an Estuary*, and *Student Data Sheet—GTM 2002-3 Nutrient Data.*

## Procedure

### Part 1 — Nutrients in an Estuary

**NOTE: You may want to begin Part 1 a full two weeks before beginning Parts 2 and 3.**

1. Ask students why estuaries are one of the most productive ecosystems in the world. What conditions exist in the estuary that would make it particularly productive? *(Nutrients from land via runoff, surface tributaries, and groundwater, mixing and circulation of nutrients and oxygen by tides, abundance of food sources and protective habitats make the estuary a good place for rearing of many types of juvenile organisms and for diversity of species.)*

2. Ask students what types of nutrients estuaries need to support high productivity. *Plants and animals need nitrogen and phosphorous, as well as many other trace nutrients. Nitrogen is a component of amino acids, enzymes, DNA, and proteins.)* If your students are familiar with the nitrogen cycle, you can suggest they consider how it functions in estuaries.

3. Have teams of students brainstorm ways in which the estuary receives the nutrients it needs. Again, if your students are familiar with the nitrogen cycle, you can suggest they consider how it functions in estuaries. Have them discuss and/or record responses to the following questions:

   - How do estuaries get necessary nutrients?
   - Are these nutrients obtained and simply used up or are they cycled through the estuary?

4. Discuss the teams' brainstormed ideas and answers. Ask if it is possible for an ecosystem to get too many nutrients.

5. Introduce the lab activity as a way of investigating whether estuaries can be affected by "nutrient over-enrichment." Either explain the beakers you have prepared, or using Part 1 of the *Student Worksheet—Nutrients in an Estuary*, have your students set up the various models.

   If you have on both a fresh and salt (or brackish) source of water, have different teams of students do fresh and saltwater models. If you have only one water source, you may increase the number of variables studied. For example, besides the amount of fertilizer in each beaker, different teams could vary the amount of sunlight their six models obtain; the pH of the water samples could be altered slightly by the addition of vinegar to sets of beakers.

6. Have students complete the **Predictions** portion of the *Student Worksheet—Nutrients in an Estuary* and then discuss student predictions about the beakers.

7. Take a digital picture of each set of beakers every two or three days for two or three weeks. Or have students take their own digital images. Load the images into a data file for later comparison.

8. After students have completed their observations, display the series of images and have students complete Part 1 of the *Student Worksheet—Nutrients in an Estuary*. Discuss the models and results.

Note: Consider having students read the *Student Reading—Introduction to GTMNERR* and *Student Reading—Nutrients in an Estuary* for homework as preparation for Parts 2 and 3.

### Part 2 — Using Data to Study Eutrophication and Conditions in an Estuary

1. Have students read the *Student Reading—Introduction to GTMNERR* and *Student Reading—Nutrients in an Estuary*.
2. Project a map of the GTMNERR with Google Maps and show students where the monitoring stations are. Ask students which stations are closest to a source of salt water and which ones are relatively far away from the ocean.
3. Have students complete Part 2 of the *Student Worksheet—Nutrients in an Estuary*.
4. Discuss the readings, tasks, and questions of Part 2.

### Part 3 — Eutrophication and the Nitrogen Cycle

1. Project or have students watch the animation illustrating eutrophication and algal blooms found at: http://peconice.ipower.com/Nutrients.animation.html
2. Have students complete Part 3 of the *Student Worksheet—Nutrients in an Estuary*.
3. Discuss the questions. Have several students read their letters (question 3f) aloud to the class.

## Check for Understanding

Question 3e is the summary assessment for this activity. It directs students to "Write a short letter to the town council of this region outlining your recommendations about steps to take to reduce the amount of nutrient flow into the estuary."

## Optional Extension Inquiries

Map and analyze the area around the nearest NERRS site to your region. Have students use Google Maps, as well as other maps and resources, to create a map delineating possible sources of nutrients for the estuary (i.e., farmland and sewage treatment plants). Then have students download the past year of SWMP data for nutrients from the https://coast.noaa.gov/swmp/ site for that estuary. Finally, have students look for patterns or cycles of change in the nutrient data and then propose what point sources or natural sources might be responsible for those patterns or cycles of change.

# Teacher Worksheet with Answers
## Nutrients in an Estuary

### Part 1 — Nutrients in an Estuary

1a. How do you think the amount of fertilizer will affect the amount of algae in each of the samples?

*Answer: Student answers will vary.*

1b. How do you think the algal growth will differ between the freshwater and saltwater samples?

*Answer: Student answers will vary.*

1c. How is this experiment different from conditions in an actual estuary that receives excess nutrients?

*Answer: Student answers will vary.*

1d. How did the amount of fertilizer affect the amount of algae in each of the pond/stream samples?

*Answer: The amount of algae increases as the concentration of fertilizer increases.*

1e. How did the algal growth differ between the freshwater and saltwater samples?

*Answer: The saltier the water, the less abundant the pond algae will be.*

1f. Explain using the process of photosynthesis how the level of dissolved oxygen varies with increasing amounts of living algae.

*Answer: As algae increase in amount, more oxygen is produced thereby initially increasing DO levels in the water.*

1g. Explain using the process of decomposition how the level of dissolved oxygen would vary in the beakers as the algae die and settled to the bottom.

*Answer: Bacteria use oxygen during the process of decomposition, effectively lowering DO levels.*

### Part 2 — Using Data to Study Eutrophication and Conditions in an Estuary

2a. Compare 16-month nitrogen and chlorophyll-a values for each site. During which seasons do peak values seem to occur at most sites? Why do you think so?

*Answer: These blooms usually occur seasonally. In the northern hemisphere, they typically occur between late spring and October. Heavier use of fertilizers in the spring combined with spring rains can introduce excess nutrients to an estuary. Other conditions that favor algal blooms come into play in the months from summer to fall: bright sunlight, still water and sharp temperature gradients that keep warmer surface water and colder bottom water from mixing.*

2b. Do you see a clear pattern that shows a relationship between TN and chlorophyll-a?

*Answer: The authors of the study acknowledge: "The absence of well-defined relationships between nutrient concentration and phytoplankton biomass (i.e. chlorophyll-a) is not unusual for estuarine ecosystems, even those subject to substantial eutrophication (Borum, 1996; Cloern, 2001)." P. 15 Journal of Coastal Research, Special Issue No. 45, 2004*

2c. Which four sites seem to show the strongest correlation between TN and chlorophyll-a?

*Answer: The authors found significant correlations between chlorophyll-a and TN at all four Indian River lagoon sites, but no significant correlations between chlorophyll-a and TN within the GTM NERR sites. The sites showing the strongest correlations are Titusvillle, Vero, and Eau Gallie.*

2d. What other factors do you think determine whether or not nutrient input will cause algal blooms?

*Answer: Tidal flushing, including tidal excursion, freshwater inflows, wind, water stratification, and depth.*

2e. If the chlorophyll-a threshold for an algal bloom is 20 ug/L, which sites may have experienced algal blooms during the period of observation?

*Answer: Given the threshold of 20 ug/L, Eau Gallie had two algal blooms, while Titusville, and Vero had one each.*

2f. Looking at the chart, what conclusion can you make about the influences of nutrient loading and residence time on chlorophyll-a concentrations?

*Answer: Regions with short water residence times have lower peak phytoplankton abundance than regions with longer residence times even despite differences in nutrient load index.*

*Sites within the GTM NERR all had relatively low residence times, lower average chlorophyll-a concentrations, and generally lower peak chlorophyll-a concentrations. Residence times at Indian River Lagoon sites varied, but two of the sites had RTI of 3 and 4. These sites generally had higher average chlorophyll-a concentrations, and two sites had the highest peak chlorophyll-a concentrations.*

## Part 3 — Eutrophication and the Nitrogen Cycle

3a. Where does most of the nitrogen that flows into an estuary come from?

*Answer: Most of the nitrogen that flows into an estuary comes from runoff from the land into rivers and streams that feed into the estuary.*

3b. What is the relationship between microbial activity during algal decomposition and DO levels in an estuary?

*Answer: Bacteria break down algae and use oxygen in the process, driving DO levels lower.*

3c. What causes the daily cycle of change in dissolved oxygen content in water?

*Answer: During nighttime hours, decomposition uses oxygen but plants cannot photosynthesize so DO levels are always lower at night. Another big reason why DO goes down at night is because plants respire around the clock but only photosynthesize in the daylight.*

3d. Name three possible human-caused sources of excess nutrients in this region.

*Answer: Animal wastes, fertilizer from farms, leaking septic systems, and direct discharge of waste from industrial plants or sewage treatment plants.*

3e. What do you think the effect of a heavy rainfall event in this region would have on the:

- level of nutrients in the estuary?

  *Answer: Heavy rain washes loads of nutrients from the sources mentioned in question 3d.*

- level of dissolved oxygen in the estuary?

  *Answer: Initially the level of oxygen increases, but as algae and algal mats die, DO can decrease dramatically.*

- development of seagrass and other aquatic plants?

  *Answer: As seen in a previous image, increased algae cause decreased sunlight for seagrass to photosynthesize so growth is inhibited or stopped completely.*

- population of aquatic organisms such as clams, crabs, and snails?

  *Answer: Plunging DO levels can cause hypoxic and eventually anoxic conditions that can cause massive extinction events of certain species.*

## Assessment

3f. Write a short letter to the town council of this region outlining your recommendations about steps to take to reduce the amount of nutrient flow into the estuary.

*Students may mention moving industrial plants and limiting outflow of waste products into the estuary, and limiting grazing and farming in proximity of riverbanks.*

*A brochure written by Florida Sea Grant Extension (available at: http://ufdc.ufl.edu/IR00003044/00001 pgs 8-9*) suggests the following actions:*

1. *Limit urban development, especially along shorelines.*
2. *Preserve wetland buffers or green space and submerged aquatic vegetation associated with coastlines, rivers, and streams.*
3. *Limit the use of fertilizers on residential and commercial lawns and landscaping.*
4. *Manage storm water runoff.*
5. *Use better septic systems.*
6. *Improve sewage treatment plants.*
7. *Support efforts to improve our knowledge.*

* Hauxwell, J.; Jacoby, C.; Frazer, T.; Stevely, J. Accessed: 2008-07-30. http://www.webcitation.org/5ZhWgbRvv

# Student Reading—1
## Introduction to the Guana Tolomato Matanzas NERR

This activity focuses on the conditions for life in the Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR). The GTM Reserve encompasses approximately 75,000 acres of salt marsh and mangrove tidal wetlands, oyster bars, estuarine lagoons, upland habitat and offshore seas in Northeast Florida. It contains the northern-most extent of mangrove habitat on the east coast of the United States.

The GTM NERR is geographically separated into a northern section where the Tolomato and Guana rivers mix with the waters of the Atlantic Ocean, and a southern section along the Matanzas River, extending from Moses Creek south of Pellicer Creek. The unique Matanzas Inlet is one of the last natural, unaltered inlets on Florida's Atlantic coast.

The GTM NERR estuary is rich with scenic beauty and economic value as it produces or supports the vast majority of the commercially and recreationally valuable fish and shellfish found in the region. The submerged lands, marshes, islands and conservation lands provide important habitat for a diversity of plants and animals, including the migrating birds stopping along the Atlantic Coastal Flyway.

The coastal waters of the GTM NERR are important calving grounds for the endangered Right Whale. Manatees, Wood Storks, Roseate Spoonbills, Bald Eagles and Peregrine Falcons find refuge in the reserve.

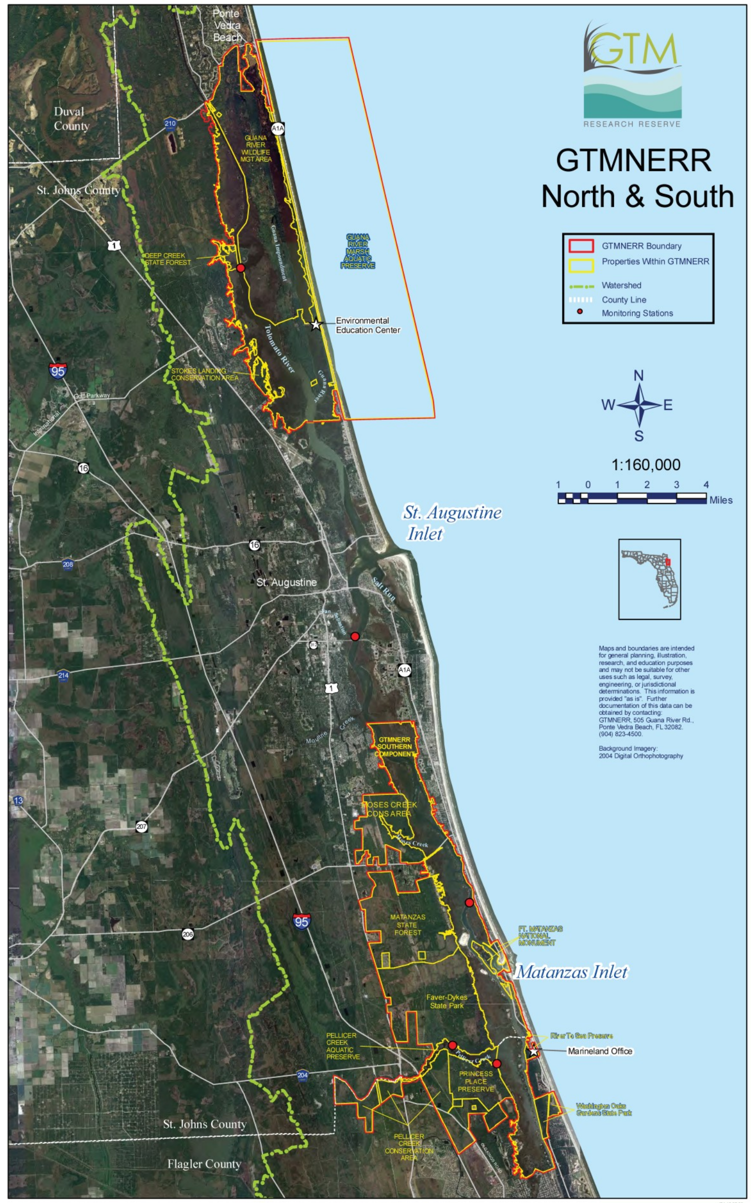


Figure 1. Guana Tolomato Matanzas National Estuarine Research Reserve boundary map.

# Student Reading—2
## Nutrients in an Estuary

### Nutrients in the Estuary

Of all the essential nutrients for life in an estuary, nitrogen and phosphorus are the two that most often limit the growth of primary producers in an estuary. Nitrogen is a key component in:

1) chlorophyll, the green pigment in primary producers that absorbs sunlight during photosynthesis,
2) amino acids, the building blocks of proteins, and
3) genetic material, including deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

Nitrogen ranks as the fourth most abundant chemical element in living tissue, behind oxygen, carbon, and hydrogen. Phosphorus is also a key component in DNA, and it is found in adenosine triphosphate (ATP), a molecule that is important in energy transfer and storage in living cells.

Natural sources of nitrogen include nutrients from rock weathering and animal waste entering the estuary from: stream flows; enriched, deep ocean water brought in by tides and upwelling; guano (waste) from birds; dead organisms in the water; and nitrogen gas in the atmosphere. Air contains nitrogen gas ($N_2$), but most organisms can't use it in this form. Aquatic life in estuaries needs to obtain nitrogen in forms they can use, or nitrogen that is "fixed." These forms are compounds such as nitrite ($NO_2$), nitrate ($NO_3$), ammonia ($NH_3$), and ammonium ($NO_4$). Animals get their nitrogen from feeding on plants or on other animals that have fed on plants.

### Eutrophication and Algal Blooms

An overload of nutrients is called eutrophication (Greek for "good-nutrition"). Eutrophication, the over-enrichment of nutrients, can be harmful to estuaries. Over-enrichment often causes "algal blooms" in estuaries. The influx nutrients cause excessive growth of algae that results in the water becoming cloudy, thus reducing the amount of sunlight that plants can use to photosynthesize. Large algal mats floating on the surface can block much of the light that underwater plants such as sea grasses need to survive. Disturbances to sea grass communities can in turn be harmful to other organisms like fish and crabs that depend on the grasses for food, shelter, and nursery areas. When algae dies, it sinks to the bottom where bacteria in the sediments decompose it. This process removes oxygen from the water. As bacteria decompose more algae, more oxygen is consumed. If too much oxygen is removed from deep waters, small organisms die endangering all forms of life in the estuary.

Algae blooms can disrupt food webs, damage estuarine habitats, and deplete oxygen to the extent that organisms die or move out. The conditions created by these blooms may encourage only species that can tolerate eutrophic conditions (e.g., blue-green algae). In addition, the appearance of the cloudy water and decaying algae mats, unpleasant odors, and loss of estuarine species can diminish the recreational value of estuaries.

Algal blooms may result from natural conditions, but they are also linked to excess nutrients that come from human activities. Excess nutrients may come from septic tanks, wastewater treatment plants, point source discharges from sewage and industry, exhaust from cars, emissions from industry, fertilizers from lawns, golf courses, and farms and animal waste (especially livestock). Sources of nitrogen that do not enter estuaries directly are transported to estuaries by stream flows, rain, leaching, groundwater, and storm water.

Algal bloom can be detected by measurements of chlorophyll-a. Chlorophyll-a is a pigment in algae that is involved in photosynthesis. Concentrations of chlorophyll-a are measures of algae abundance (the more chlorophyll-a, the more algae). Concentrations measured are measured in units of micrograms per liter (µg/L).

# Student Reading—2
## Nutrients in an Estuary (continued)

When water has low levels of oxygen the condition is called **hypoxia**. In estuaries, lakes, and coastal waters, low oxygen usually means a concentration of less than 2 parts per million. **Anoxia** refers to water that has been completely depleted of oxygen. Anoxic conditions may force crabs and other bottom-dwelling organisms to even come up on land to escape oxygen starvation. These events are called "jubilees." Large areas of estuaries where organisms have died off or vacated for lack of sufficient oxygen are called dead zones. Some estuaries experience dead zones regularly.

Figure 2. The formation of algae mats can lead to conditions harmful for both plants and animals living in the estuary. (Photo Credit: NOAA)

# Student Worksheet
## Nutrients in an Estuary

Student Name ______________________________________________

## Part 1: Nutrients in an Estuary

In this part of the activity, you will produce models of estuaries that have an increasing amount of nutrient added to them in order to address the following question: **What effects does increasing the amount of nutrients in an estuary have on plant growth, on the amount of dissolved oxygen, and on other water quality factors that impact life in an estuary?**

Your model will consist of a series of 600 ml beakers containing water samples with algae. You will add nutrients, in the form of commercial fertilizer, to each beaker and then monitor the samples once a week, measuring the water quality parameters and describing the algae growth.

### Instructions

Put on your goggles! It is very important that you wear them when adding fertilizer to the beakers.

Label one beaker: *No added nutrients*. Also include details about the nature of the water sample (e.g. fresh water or salt water) on the labels.

Label another beaker: *1 teaspoon nutrients*. Add 1 tsp of fertilizer to this beaker and stir until the fertilizer is dissolved.

Repeat for additional beakers with 2, 3, 4, and 5 teaspoons of nutrients in each.

Place the beakers on a counter situated so all the beakers receive about the same amount of sunlight per day.

Record information on the contents of each beaker, using this technique to see inside:

- Stand with your back to a light source so it is shining over your shoulder and through the beaker.
- Place a white piece of paper behind the beaker (on the opposite side of the light source).
- Describe and/or draw any algae you can see in the beaker. (You may not see any algae, especially at the beginning. If that's the case, record, "No algae visible.")

Take digital images of all six beakers and note the time and date you took the pictures.

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**Making Predictions**

1a. How do you think the amount of fertilizer will affect the amount of algae in each of the samples?

1b. How do you think the algal growth will differ between the fresh and salt-water samples?

1c. How is this experiment different from conditions in an actual estuary that receives excess nutrients?

## Tracking the Models Over Time

Examine the contents of your beakers, using the technique from the instructions above, and record your observations every two or three days over a period of three weeks. Also, take a digital image every two or three days. At the end of three weeks, display all images and observe the changes in your model estuaries.

1d. How did the amount of fertilizer affect the amount of algae in each of the samples?

1e. How did the algal growth differ between the fresh and salt water samples?

1f. Explain using the process of photosynthesis how the level of dissolved oxygen varies with increasing amounts of living algae.

1g. Explain using the process of decomposition how the level of dissolved oxygen would vary in the beakers as the algae die and settled to the bottom.

## Part 2 — Using Data to Study Eutrophication and Conditions in an Estuary

In this part of the activity, you will investigate how nutrients affect of algal blooms on water quality at various stations within the GTM NERR site. Using the graphs and chart on the *Student Data Sheet—GTM 2002-3 Nutrient Data*, answer the following questions.

2a. Compare 16-month nitrogen and chlorophyll-a values for each site. During which seasons do peak values seem to occur at most sites? Why do you think so?

2b. Do you see a clear pattern that shows a relationship between TN and chlorophyll-a?

2c. Which three sites seem to show the strongest correlation between TN chlorophyll-a?

2d. What other factors do you think determine whether or not nutrient input will cause algal blooms?

2e. If the chlorophyll-a threshold for an algal bloom is 20 ug/L, which sites may have experienced algal blooms during the period of observation?

2f. Looking at the chart, what conclusion can you make about the influences of nutrient loading and residence time on chlorophyll-a concentrations?

## Part 3—Eutrophication and the Nitrogen Cycle

In order for organisms to survive in an estuary, a constant source of nutrients must be present for them to consume. But as you have seen, *too* many nutrients flowing into an estuary can lead to anoxic conditions and even massive die-offs of animal and plant species. In this part of the activity, you will be asked to review your work and examine the effect of nutrients on other abiotic factors that ultimately determine the welfare of species in the estuary.

To summarize your investigations about nutrients in an estuary, view the series of animations at: http://coseenow.net/blog/2008/11/eutrophication-animation

3a. Where does most of the nitrogen that flows into an estuary come from?

3b. What is the relationship between microbial activity during algal decomposition and DO levels in an estuary?

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This is a simplified diagram of how the nitrogen cycle works in an estuary. Examine the cycle in detail.

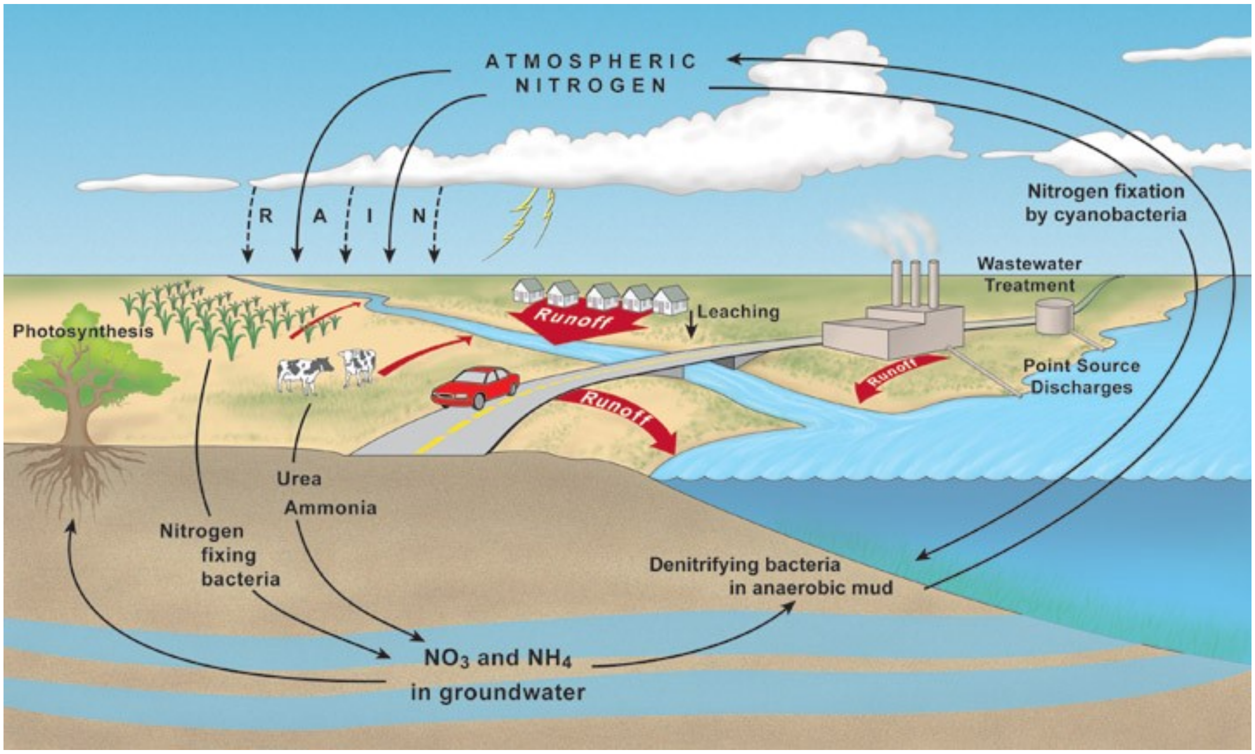


Figure 3. Nutrients and Florida's Coastal Waters: The Links Between People, Increased Nutrients and Changes to Coastal Aquatic Systems. <http://ufdc.ufl.edu/IR00003044/00001>. Published by the Florida Sea Grant College Program with support from the National Oceanic and Atmospheric Administration, Office of Sea Grant, U.S. Department of Commerce. Published for the University of Florida, Institute of Food and Agricultural Sciences (SGEB-55). October 2001. (Archived by WebCite® at http://www.webcitation.org/5ZhWSaa3M)

Imagine that the estuarine system shown in the diagram has a dangerously high level of nutrients.

3c. Name three possible human-caused sources of excess nutrients in this region.

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3d. What do you think the effect of a heavy rainfall event in this region would have on the:

- level of nutrients in the estuary?

- level of dissolved oxygen in the estuary?

- development of seagrass and other aquatic plants?

- population of aquatic organisms such as clams, crabs, and snails?

## Assessment

3e. As a summary assessment, write a short letter to the town council of this region outlining your recommendations about steps to take to reduce the amount of nutrient flow into the estuary.

# Student Data Sheet
## GTM NERR 2002-3 Nutrient Data

**Page 1 of 4**

May 2002 to August 2003, researchers at the GTM NERR in Florida studied how nutrients, water quality parameters, and physical factors affect algae abundance in the lagoons of East Florida. Over a sixteen-month period, they measured nutrient levels and algae abundance (determined by gauging chlorophyll-a concentrations) at eight sites in the reserve. The study also analyzed total nitrogen (TN) and dissolved inorganic nitrogen (DIN) concentrations and chlorophyll-a concentrations at all eight sites.

The chance that particular sites within estuaries will experience algal blooms depends on a number of conditions. These include:

- The amount of nutrient input.
- Water quality parameters such as temperature and salinity.
- Weather and seasonal conditions.
- The residence time of nutrients in the estuary. This is determined by factors such as stream flow, tidal flushing, winds, water depth, and water stratification.

These factors determine whether nutrients will stay in the estuary long enough to alter the nitrogen cycle enough to instigate an algal bloom.

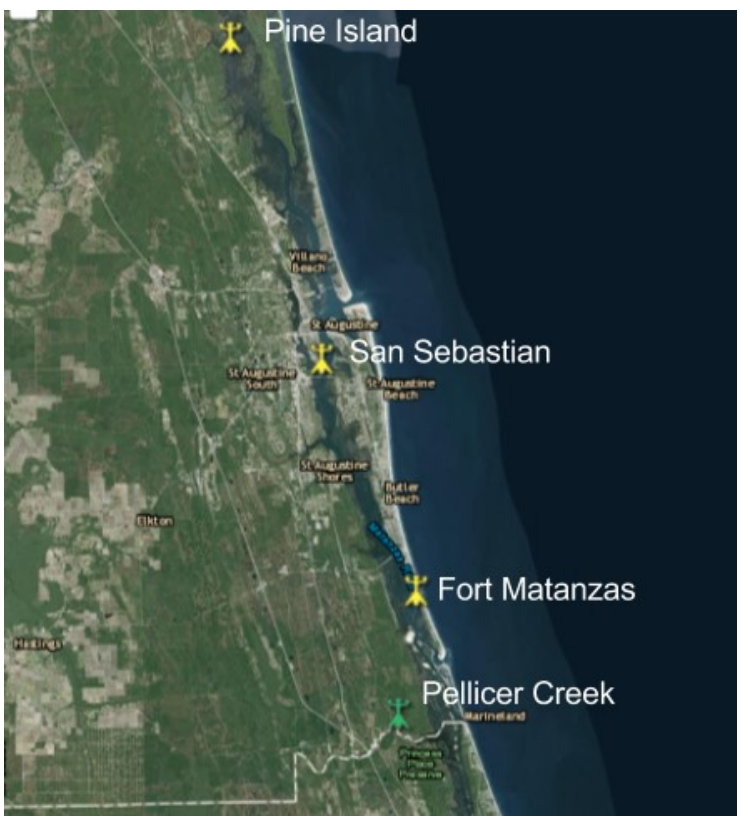


Figure 4. A satellite image of the GTM NERR estuary with some of the monitoring stations you will be investigating.

## Graphs

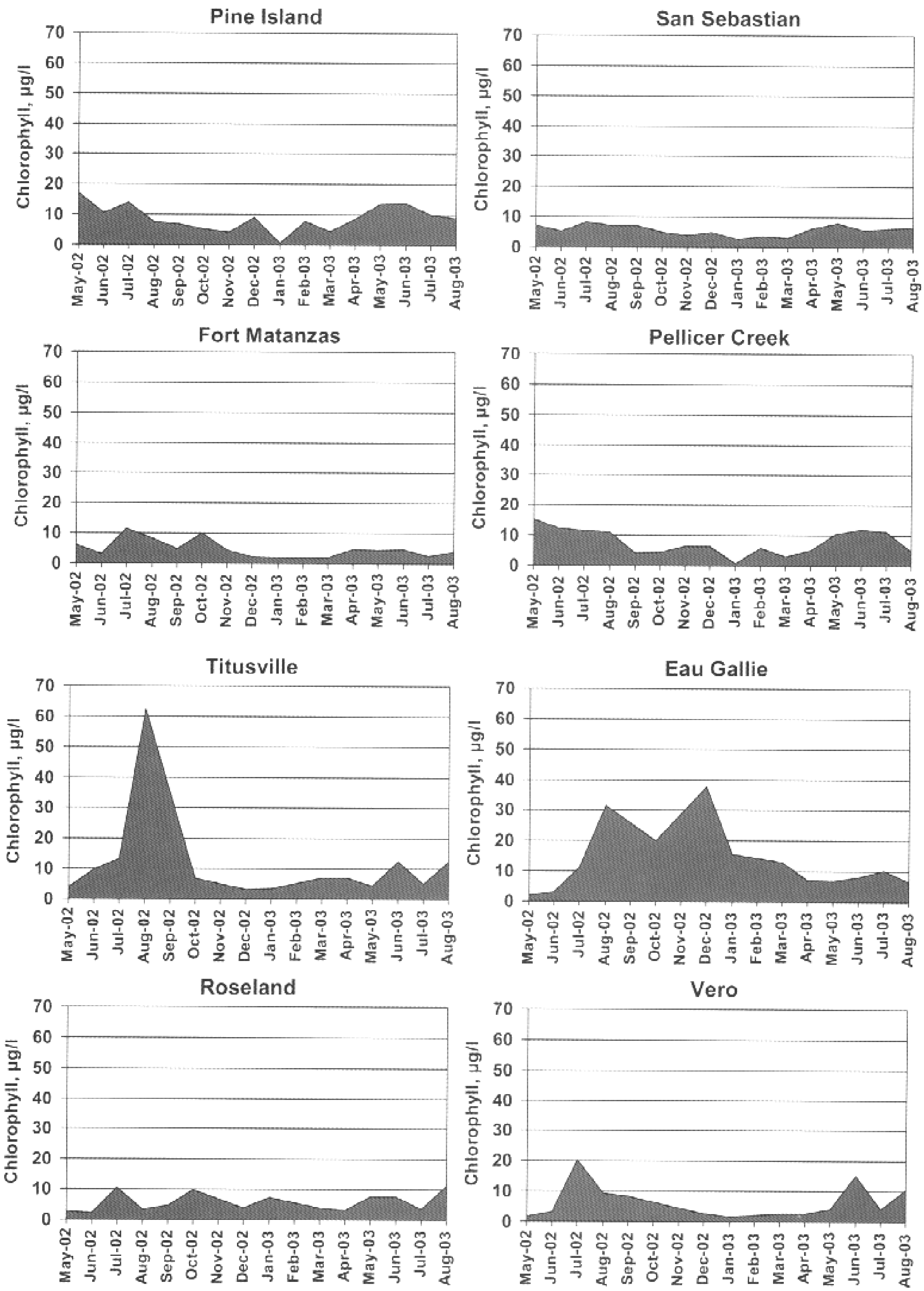


Figure 5. Chlorophyll-a concentration at eight study sites

**Page 3 of 4**

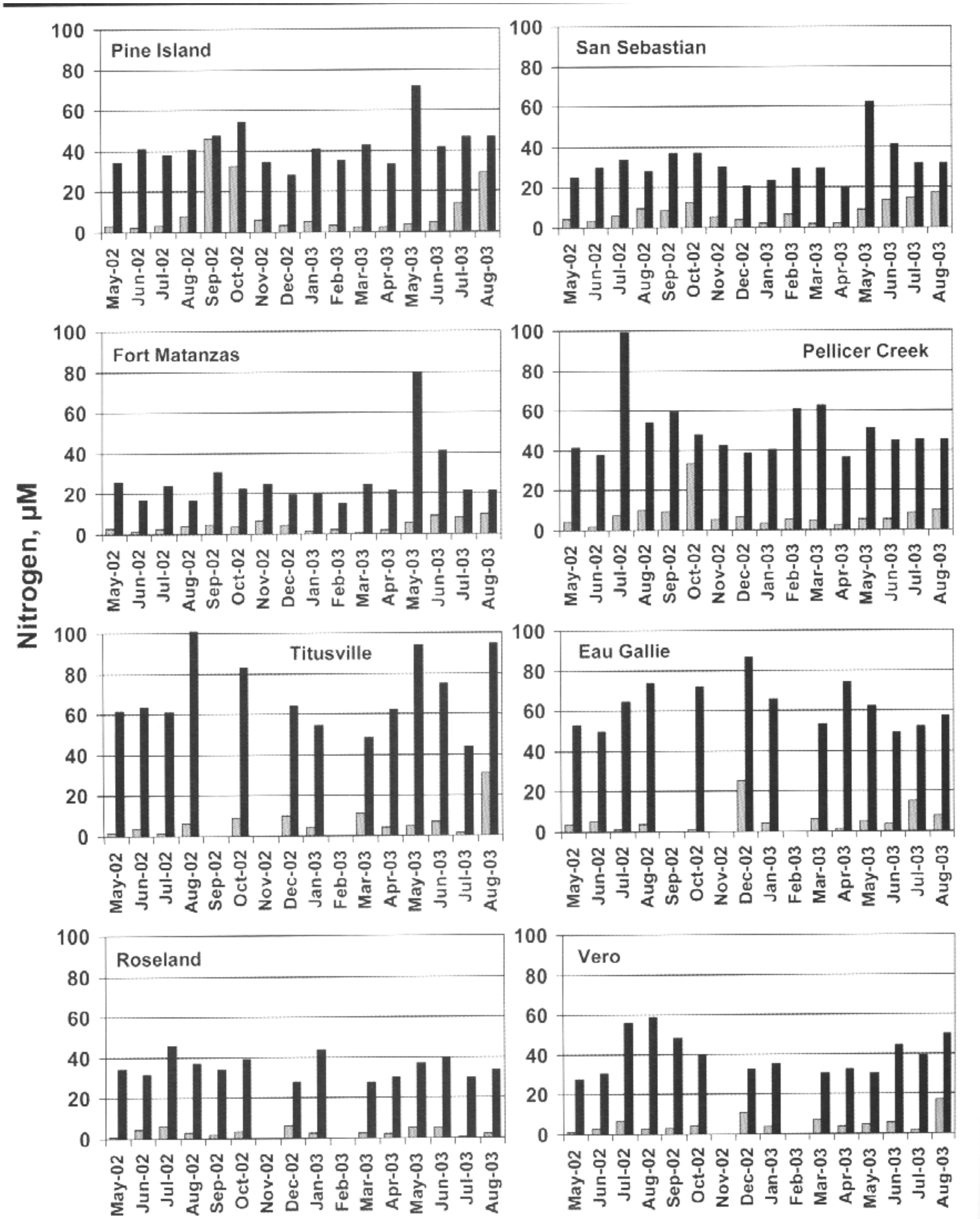


Figure 6. Total nitrogen (solid bar) and dissolved inorganic nitrogen (gray bar) concentrations at eight sampling sites

## Chart

Researchers at the reserve considered all the factors that determine nutrient loading (including nitrogen and phosphorous inputs from all sources) and developed an index (Nutrient Load Index, or **NLI**), from 1-4, that describes how heavily the site is usually loaded with nutrients (1 represents a low load, 4 represents a high load).

They also developed an index categorizing the sites according to estimated water residence times (**RTI**) on a scale of 1-4. This was done by summarizing the factors that determine tidal flushing, including tidal excursion, freshwater inflows, wind, water stratification, and depth. The index describes the extent to which nutrients generally remain in the estuary, or are flushed out (1 represents a short residence time, 4 represents a long residence time).

| **Site** | **Nutrient Load Index** | **Residence Time Index** | **Peak chlorophyll-*a*** | **Average chlorophyll-*a*** |
|---|---|---|---|---|
| GTM NERR Sites | | | | |
| Pine Island | 1 | 2 | 18 | 8 |
| San Sebastian | 3 | 1 | 5 | 8 |
| Fort Matanzas | 1 | 1 | 8 | 11 |
| Pellicer Creek | 3 | 2 | 10 | 15 |
| Indian River Lagoon Sites | | | | |
| Titusville | 1 | 1 | 4 | 22 |
| Eau Gallie | 2 | 2 | 3 | 20 |
| Roseland | 4 | 4 | 1 | 10 |
| Vero | 4 | 4 | 2 | 12 |